Performance of the 16-ID-B Bimorph Mirrors

Daniel Häusermann
HPCAT – Sector 16
(Carnegie Institution of Washington)

Thank you to:
All the HPCAT staff members who have worked on this project, especially
Maddury Somayazulu

Riccardo Signorato
(ESRF - SPring-8 - ACCEL)

- Introduction: Focusing for High Pressure studies
- HPCAT facility: Brief overview
- Principle of bimorph mirrors and their history
- 16ID-B K-B bimorphs
  - Performance: Optical and X-ray
  - Control
  - Stability
- Conclusion and plans for the future
# Modular Bimorph mirrors installed base

<table>
<thead>
<tr>
<th>Mirror No.</th>
<th>Facility</th>
<th>Mirror Length</th>
<th>Functionality</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ESRF</td>
<td>750 mm</td>
<td>HFM in a K-B setup</td>
<td>Operational. Routinely used at ID26 since 1997</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>2</td>
<td>ESRF</td>
<td>450 mm</td>
<td>VFM in a K-B setup</td>
<td>Operational. Routinely used at ID26 since 1998</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>3</td>
<td>ESRF</td>
<td>450 mm</td>
<td>VFM in a double mirror system</td>
<td>Operational. Routinely used at ID 32 since 1997</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>4</td>
<td>SPring-8</td>
<td>300 mm</td>
<td>Movable, quick installation HFM/VFM for the RIKEN beamlines</td>
<td>Operational. Routine use since 2000 at three different beamlines</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>5</td>
<td>SPring-8</td>
<td>300 mm</td>
<td>R&amp;D on chemical superpolishing; extra-wide dynamical range</td>
<td>To be polished by Osaka University</td>
<td>M / PI / B</td>
</tr>
<tr>
<td>6</td>
<td>APS</td>
<td>300 mm</td>
<td>K-B microfocusing mirrors</td>
<td>Operational. Routinely used at HP-CAT since Nov. 2002</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>7</td>
<td>APS</td>
<td>300 mm</td>
<td>K-B microfocusing mirrors</td>
<td>Operational. Routinely used at HP-CAT since Nov. 2002</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>8</td>
<td>APS</td>
<td>600 mm</td>
<td>VFM in a K-B setup</td>
<td>Being manufactured</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>1050 mm</td>
<td>HFM in a K-B setup</td>
<td>Being manufactured</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>600 mm</td>
<td>VFM in a K-B setup</td>
<td>Being manufactured</td>
<td>M / FS / MC</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>1050 mm</td>
<td>HFM in a K-B setup</td>
<td>Being manufactured</td>
<td>M / FS / MC</td>
</tr>
</tbody>
</table>

B = bare reflecting surface  
C = cooled mirror  
M = mirror exposed to monochromatic beam only  
P = mirror exposed to pink beam  
FS = reflecting plates material: fused silica  
MC = metallic coating (Pt, Rh, Cr …)  
PI = reflecting plates material: pirex glass  
SI = reflecting plates material: silicon  
HFM = horizontally focusing mirror  
VFM = vertically focusing mirror

**NOT IN TABLE:**  
Prototype 150mm K-B (single electrode) pair successfully used on High-Pressure Beamline (ID30) from 1996 to 1997 BUT not very stable and required frequent re-optimisation for best focal spot (~every few days for very best focal spot of ~ 15µm x 20µm, but asymmetric)
**PBM's bending principle**

The inert plates on top of PZT1 and on the bottom of PZT2 are not represented for sake of clarity. The control electrode is situated at the Pzt-Pzt bonding interface. \( V_D \) represents the high voltage power supply.

**Calibration curve**

The squares represent the different measuring points.
Characteristics of 16-ID-B KB bimorph mirrors

TOTAL LENGTH: 300 mm
OPTICAL LENGTH: 260 mm minimum
NUMBER OF PZT SEGMENTS: 2, each 150 mm long
PZT MATERIAL: Zirconate lead titanate ceramic
INERT TOP AND BOTTOM PLATE: Fused silica
METALLIC COATING: Pt
NUMBER OF ELECTRODES: 8
HIGH VOLTAGE RANGE: +/- 1500 V
with possibility for extension to +/- 2000 V

GRAVITY SAG COMPENSATION: Not implemented as it is not needed
FUNCTIONALITY: Exchangeable HFM – VFM (see next point)
HOLDER: Each holder allows quick mounting in two orthogonal positions
ELECTRONICS: Use of an extremely high stability, accuracy and resolution HV supply
CONTROL SOFTWARE: Currently dedicated software with LabView GUI, EPICS version under development
HV CHANNELS: All 8 electrodes of each mirror can be driven independently

VACUUM REQUIREMENTS: UHV compatible, but air / N2 / He OK
[TOP] shape error before –dashed- and after –solid- adaptive correction of the mirror shape. The bimorph can be shaped to a perfect sphere with a residual shape error as small as 100Å rms. [BOTTOM] PSD function at $V_D = 0V$ & 600V on all electrodes and after adaptive correction (each electrode is independently set at a different $V_D$). Low frequency components of the PSD could be reduced by as much as 4 orders of magnitude.
Repeatability and Hysteresis determination. The first three repeated measurements at 0V were carried out in order to characterize the repeatability of the LTP itself. The same voltage was applied to all electrodes and the cycle was carried out following the order for $V_D$ as presented in the following table.

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Spherical best fit radius (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>632.0</td>
</tr>
<tr>
<td>0</td>
<td>631.1</td>
</tr>
<tr>
<td>0</td>
<td>631.7</td>
</tr>
<tr>
<td>+500</td>
<td>516.8</td>
</tr>
<tr>
<td>+1000</td>
<td>435.7</td>
</tr>
<tr>
<td>+500</td>
<td>517.7</td>
</tr>
<tr>
<td>+1000</td>
<td>436.4</td>
</tr>
<tr>
<td>+1500</td>
<td>374.2</td>
</tr>
<tr>
<td>+1000</td>
<td>434.1</td>
</tr>
<tr>
<td>+500</td>
<td>517.0</td>
</tr>
<tr>
<td>0</td>
<td>634.6</td>
</tr>
<tr>
<td>-500</td>
<td>842.5</td>
</tr>
<tr>
<td>+500</td>
<td>515.8</td>
</tr>
</tbody>
</table>

Determination of short and long term drifts in $R$ for a given $V_D$

<table>
<thead>
<tr>
<th>Short term stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>T0</td>
</tr>
<tr>
<td>T0 + 15 hours</td>
</tr>
</tbody>
</table>

$\Delta R/R \equiv 0.8\%$

<table>
<thead>
<tr>
<th>Long term stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
</tr>
<tr>
<td>T0 + 8 days</td>
</tr>
<tr>
<td>T0 + 9 days</td>
</tr>
</tbody>
</table>

$\Delta R/R \equiv 2.0\%$
Beam profiles recorded immediately upstream of the bimorph K-B. Both projections of the beam intensity show highly structured profiles and/or lack of symmetry due to upstream optical elements (attenuators and crystals, see text)
Incident beam: 0.5 x 0.5 mm
Angle: 2 mrad
Energy: 29.4 keV
Distance from HFM: 750 mm
Distance from VFM: 1050 mm
Applied Voltages (V)
-7.8
-207
-557
-887
-687
-887
-837
-837

Vertical focussed beam from 0.4 mm acceptance at 3 mrad
E = 21 keV
0.1 um step scan with slits
Gaussian fit yields fwhm = 4.97 um
Applied Voltages (V)

-340
-340
-640
-640
-500
-500
0
0

Horizontal Focal spot from 0.5 mm incident beam scan at 0.1 um increment; fwhm = 0.8 um
Nitrogen at 155 GPa
cBN gasket : 18 um dia
Summary

- EXTREMELY HIGH OPTICAL QUALITY
- VERY STABLE
- ADAPTIVE ZONAL CONTROL
- WAVEFRONT CORRECTION
- VERY REPRODUCIBLE

- FAST FOCAL DISTANCE,
  HENCE FOCAL SPOT SIZE CHANGE

- HIGH QUALITY CLEAN FOCAL SPOT

Status

- ROUTINE OPERATION ON 16-ID-B
  SINCE NOVEMBER 2002

- AUTOMATIC OPTIMIZATION PROGRAM
  UNDER DEVELOPMENT (Sept 03)

- More mirrors about to be ordered:

  - Up to 600 mm long
  - Some with cooling channels for white beam
  - Several coating strips including multi-layers
  - Maybe with COATINGS ON BOTH SIDES
  - New electronics